

Workshop: An Iranian astrolabe from the 4th century Hijra

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This workshop is based on a workshop by prof. dr. Jan P. Hogendijk, Utrecht and Leiden University, which has been held on several occasions in The Netherlands and the I.R. of Iran. The hand-drawn astrolabe model of Mr. Hogendijk has been replaced by a computer-generated model.



Figure 1: The astrolabe of the Iranian mathematician and astronomer Al-Khujandī.

For more than thousand years the astrolabe was one of the most used astronomical instruments in both the Islamic World and Europe. Based on mathematical principles which go back to Greek antiquity, the astrolabe flourished in the Islamic World from the year 200 AH onwards. In this workshop the participants

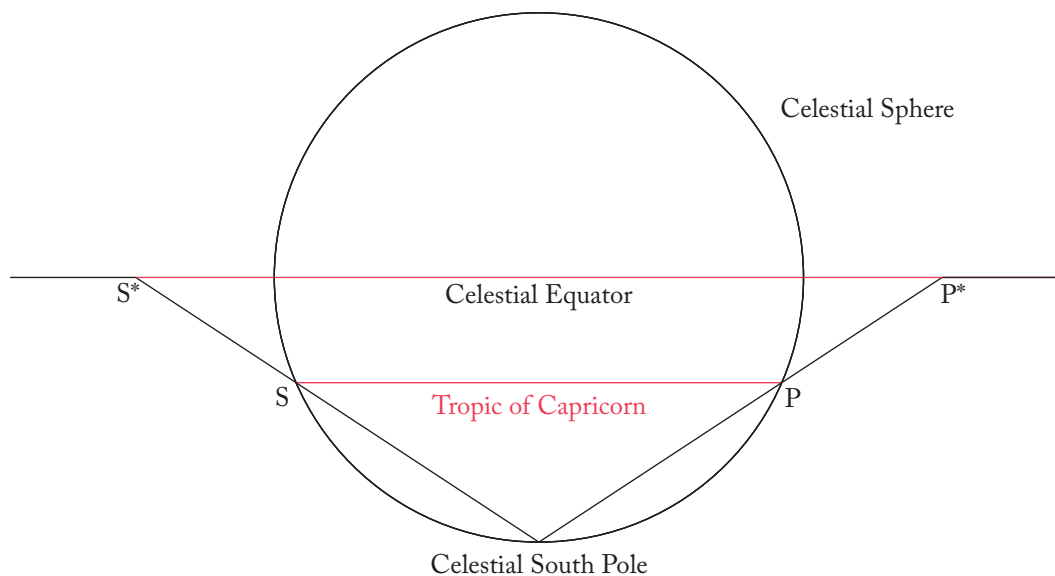


Figure 2: Stereographic projection of the Tropic of Capricorn of the celestial sphere onto the plane of the celestial equator.

will learn how to use the astrolabe. We will use a model which is based on the astrolabe constructed by the Iranian mathematician and astronomer Abū Maḥmūd Ḥāmid ibn al-Khiḍr Al-Khujandī in the year 374 AH at the observatory in Baghdad. It is one of the oldest astrolabes extant today. Its many uses include locating and predicting the positions of the sun and stars, for instance to schedule prayer times, and determining the local time. The astrolabe could also be used as a compass.

Principles

The astrolabe is based on the mathematical principles of the *celestial sphere* and *stereographic projection*. The celestial sphere is an imaginary sphere concentric with the Earth on which the stars and the apparent path of the sun in particular are projected from the center of the Earth. Stereographic projection is a method to map a sphere onto a plane, in this case the celestial sphere is mapped from the celestial south pole onto the plane of the celestial equator.

The astrolabe model consists of two parts:

On the overhead sheet: the spider

The spider contains the stereographic projections of the *ecliptic*, which is the apparent one year trajectory of the sun along the sky, and of 33 astrolabe stars. The astrolabe stars are the same as on the astrolabe of Al-Khujandī. The positions of the stars are recomputed for the year 1421 AH, showing the effect of precession of the equinoxes if the model is compared to the original

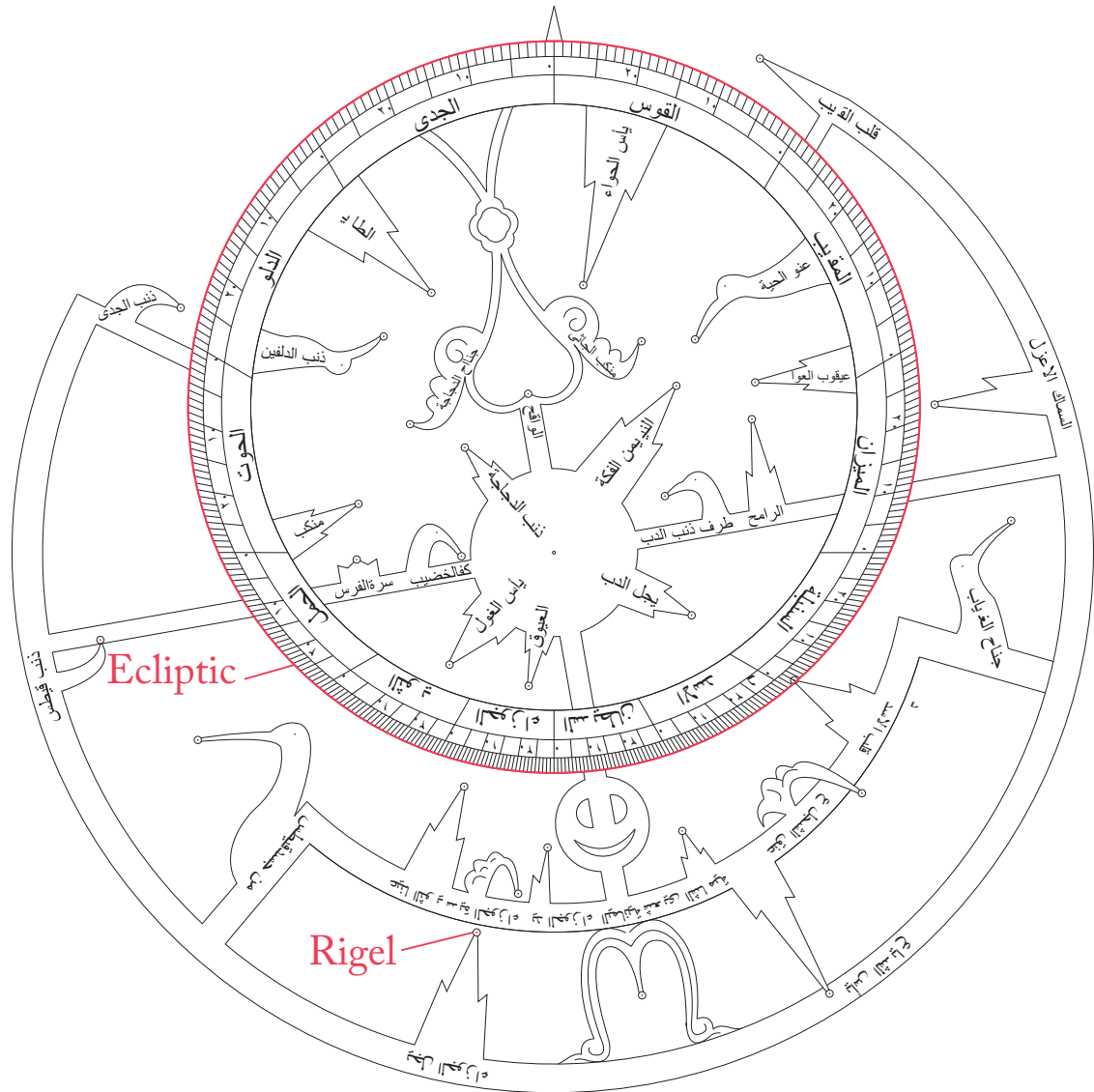


Figure 3: The spider with the ecliptic and the star Rigel highlighted.

astrolabe of Al-Khujandī. The precession is about 15 degrees in a 1000 year interval. In the model, the position of a star is indicated by a dot in the middle of a small circle.

On the paper: the plate

The plate has been recalculated for the geographical latitude of 33 degrees, that is for Esfahan. The plate has been combined with the rim, which is a circular scale divided into 360 degrees. The plate displays (parts of the) the stereographic projections of the following points and circles:

- The centre of the plate is the *celestial north pole*, which is the centre of three concentric circles: the *Tropic of Cancer*, the *celestial equator* and the *Tropic of Capricorn*.
- The *horizon*, which projection is visible on the plate in Eastern, Northern and Western directions. The *twilight line* is 18 degrees below the horizon.
- The *almuqantarāt* (altitude circles) are the nearly concentric circles 3, 6, 9, ... degrees above the horizon.
- The *zenith* is the point directly above the head of the observer, i.e. 90 degrees above the horizon.
- The *azimuthal circles* or circles of equal direction. Its projections are drawn for 5 degree intervals and are numbered at their intersections with the horizon. The *first vertical* is the azimuthal circle through the East and the West point. It is the reference circle for the other azimuthal circles. Note that all azimuthal circles pass through the zenith.

Note. The back side of the astrolabe is not shown in this model. It contains the alidade: a metal strip with two sights and a pointer. An alidade can be used to measure the altitude of the sun or a star in degrees, if the astrolabe is suspended vertically. The altitude can be read off on a circular scale.

Use of the astrolabe

If one knows the position of the sun in the ecliptic on a given day, the astrolabe can be used to tell the local time and can also be used as a compass. The position of the sun can be estimated using the fact that the sun moves through the twelve zodiacal signs, into which the ecliptic is divided, in the course of one year. Every sign is divided into 30 degrees. The sun moves with a velocity of approximately one degree per day. The Iranian months correspond to the zodiacal signs, for example, on 10 Dey, the sun is in 10 Capricornus. In Table 1 the zodiacal signs and their corresponding months are listed.

For any day, the position of the sun in the ecliptic can be marked on the spider by a non-permanent marker. The altitude of the sun can be measured using the alidade on the back side of the astrolabe. The spider can now be set to represent the actual position of the celestial constellations with respect to the horizon. By means of the azimuthal circles one can read off the direction of the sun, for example 10 degrees South of East. To determine the local time, note that the pointer of the spider indicates a number on the rim. A full rotation of the spider corresponds to 24 hours, so 1 degree of rotation corresponds to 4 minutes of time. By rotating the spider, one can determine the interval of time between the moment of observation and, for example, sunset, noon, and sunrise.

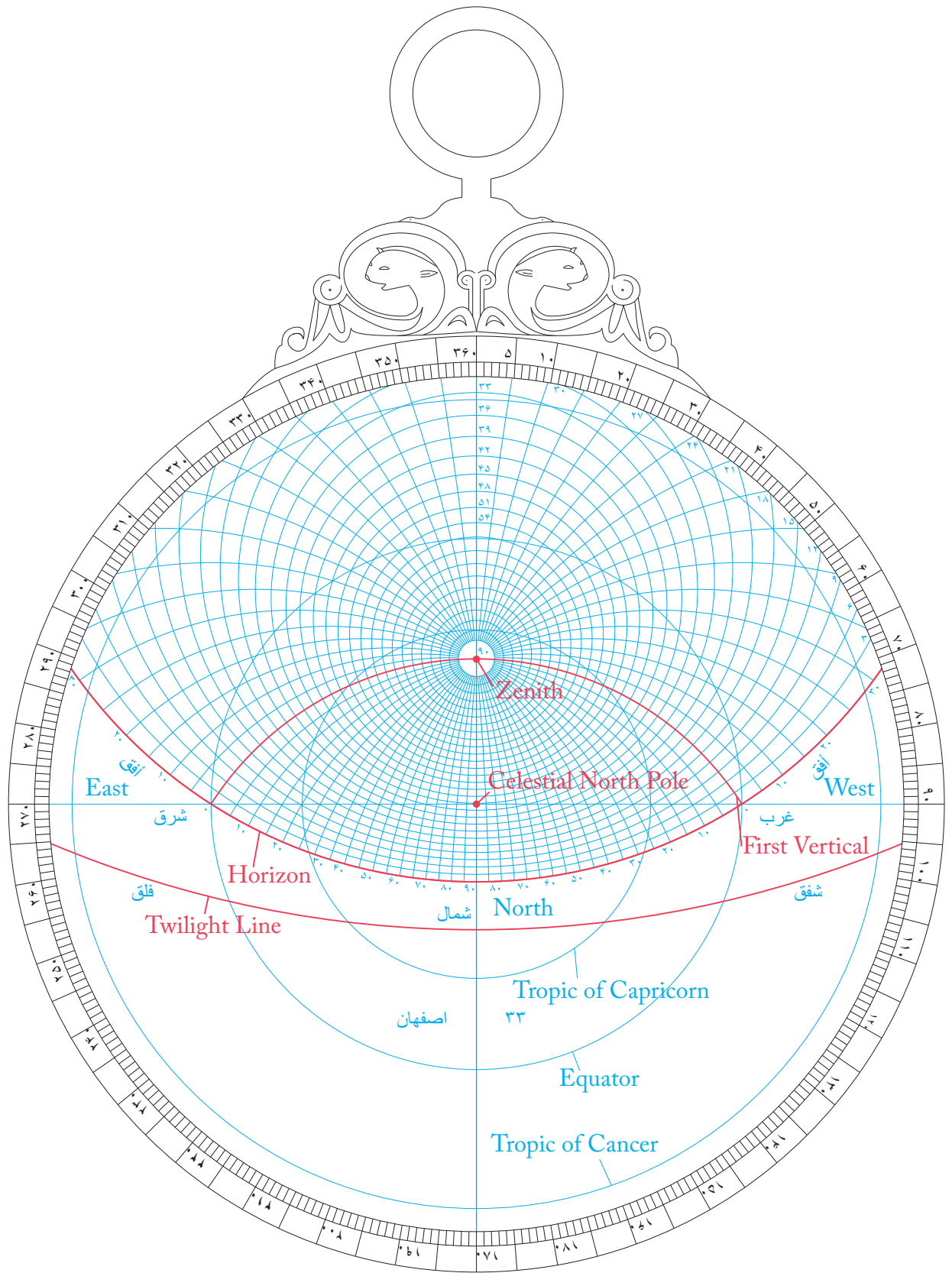


Figure 4: The front side of the astrolabe model.

Aries	الحمل	Farvardin	فروردین
Taurus	الثور	Ordibehesht	اردی بهشت
Gemini	الجوزأ	Khordad	خرداد
Cancer	السرطان	Tir	تیر
Leo	الاسد	Mordad	مرداد
Virgo	السنبلة	Shahrivar	شهرور
Libra	الميزان	Mehr	مهر
Scorpio	العقرب	Aban	آبان
Sagittarius	القوس	Azar	آذر
Capricornus	الجدي	Dey	دی
Aquarius	الدلو	Bahman	بهمن
Pisces	الحوت	Esfand	اسفند

Table 1: The zodiacal signs in both Latin and Arabic, and the Iranian months which coincide with the zodiacal signs.

Astrolabe Workshop

Level 1

1. The date of your anniversary is: day, month
2. Then the sun is in the sign of the zodiac:
3. And in the degree: In case the degree is 31, write 30.

Now mark the position of the sun on the ecliptic on the spider. Be sure to mark it on the outer rim of the ecliptic!

4. At sunrise on your anniversary, the position of the pointer is: Recall that the sun rises at the Eastern horizon.
5. At sunset on your anniversary, the position of the pointer is:
6. The difference between the position of the pointer at sunset and the position of the pointer at sunrise is: degrees. When encountering a negative difference, add 360 degrees to the position of the pointer at sunset.
7. The length of daylight on your anniversary is: Recall that 15 degrees corresponds to 1 hour.

Level 2

Suppose you have measured with the alidade on the back side of the astrolabe that the sun is 9 degrees above the horizon. You have done the measurement in the afternoon of your anniversary date.

8. The position of the pointer at that moment is:
9. The position of the pointer at noon (12.00 true local solar time) is:
10. The difference between the position of the pointer at the moment that the sun is 9 degrees above the horizon and the position of the pointer at noon is: degrees.
11. The true local solar time at the moment that the sun is 9 degrees above the horizon is:
12. The direction of the sun at that moment is:

Bonus Level

Suppose you are at a place with the same latitude as Esfahan. The geographical longitude of this place is 15 degrees East of Mecca. You know that the sun passes through the zenith of Mecca on the days when it is in 7 Gemini and in 23 Cancer.

13. Use the astrolabe to find the direction of prayer, *qibla*, at your place.